

REMARKS

In view of the above amendments and the following remarks, reconsideration of the rejections and further examination are requested. Upon entry of this amendment, claims 1-3, 5-10 and 12 are amended, claims 4 and 11 are canceled and claims 13-23 are added, leaving claims 1-3, 5-10 and 12-23 pending with claims 1 and 13 being independent. No new matter has been added.

Objections to the Drawings

The drawings have been objected to because the Examiner contends that block elements 39 and 49 in Fig. 3, 41a-d in Fig. 4, 41 and 47 in Fig. 6 and 11-18 in Fig. 8 should be labelled using appropriate legends.

The drawings have been amended to overcome this objection.

Additionally, the drawings are objected to since the tapping electrodes are not shown therein. Claim 11 has been cancelled to overcome this objection.

Rejections Under 35 U.S.C. §112, first paragraph

The specification has been rejected under 35 U.S.C. § 112, first paragraph, for failing to be written in “fill, clear, concise, and exact terms.”

The specification has been amended to overcome this rejection.

Rejections Under 35 U.S.C. §112, second paragraph

Claims 1-12 have been rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

Claims 1, 3, 4, 7, 8 and 12 have been amended to overcome this rejection.

Rejections Under 35 U.S.C. §102(b)

Claims 1-3, 5, and 12 have been rejected under 35 U.S.C. § 102(b) as being anticipated by Howe et al. (U.S. 4,805,456).

Amended independent claim 1 overcomes this rejection. Claim 1 now generally recites, among other things, a vibration piezoelectric acceleration sensor including a support body supporting the first pair of beam shaped members, the support body being adjacent to one end of each beam shaped member, and a holding part holding the support body in a linear direction, wherein the holding member is constructed and arranged in a meandering manner.

Amended independent claim 1 now recites the subject matter of dependent claim 4, i.e., that the holding member is constructed and arranged in a meandering manner. Applicants submit that the prior art fails to disclose or render obvious this element. This is recognized by the Examiner, since the Examiner did not reject this claim (i.e., claim 4) using Howe.

Therefore, Applicants submit that independent claim 1 and its dependent claims are allowable over the cited prior art.

Rejections Under 35 U.S.C. §103(a)

Claims 6 and 9 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Howe et al.

Claims 10 and 11 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Howe in view of Noritomo et al. (JP 09-211020).

Independent claim 1 is allowable over these references for similar reasons to those discussed above. Namely, none of the cited prior art discloses or renders obvious a holding member constructed and arranged in a meandering manner.

New Claims 13-23

New claims 13-23 are allowable over the cited prior art. Independent claim 13 recites, a vibration piezoelectric acceleration sensor including, among other things, a first pair of beam shaped members linearly and oppositely disposed on the frame, a second pair of beam shaped members linearly and oppositely disposed on the frame, the first pair of beam shaped members being disposed on a first line crossing a second line on which the second pair of beam shaped members are disposed, a support body supporting the beam shaped members, the support body being adjacent to one end of each beam shaped member, and a holding part holding the support

body in a linear direction, the holding part being located between one of the first pair of beam shaped members and one of the second pair of beam shaped members.

Thus, claim 13 recites at least four beam shaped members and at least one holding part. Fig. 1a of Howe (U.S. 4,805,456) discloses an accelerometer including four alleged beam shaped members; however, Howe fails to disclose a holding part as recited in claim 13. Furthermore, there is no reasoning in Howe to alter the device disclosed therein such that it would render claim 13 obvious. Additionally, none of the other cited references overcome the deficiencies of Howe.

Therefore, Applicants submit that independent claim 13 and its dependent claims are allowable over the cited prior art.

In view of the foregoing amendments and remarks, all of the claims now pending in this application are believed to be in condition for allowance. Reconsideration and favorable action are respectfully solicited.

Should the Examiner believe there are any remaining issues that must be resolved before this application can be allowed, it is respectfully requested that the Examiner contact the undersigned by telephone in order to resolve such issues.

Respectfully submitted,

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DESCRIPTION

VIBRATION PIEZOELECTRIC ACCELERATION SENSOR

This application is a U.S. national phase application of PCT

5 International Application PCT/JP2005/002126

TECHNICAL FIELD

The present invention relates to a vibration piezoelectric acceleration sensor (hereinafter, called VAS) to be used for a posture controller, and a
10 vehicle and other mobile equipment control system.

BACKGROUND ART

Fig. 7 is a cross sectional view of a conventional acceleration sensor. As shown in Fig. 7, diaphragm 2 is formed in a rear side of chip 1, and a plurality 15 of distortion sensing resistors 3 are disposed on a surface side of the chip, (*i.e.*, an opposing side of the diaphragm ~~formed from the rear side~~). At ~~an other part~~
~~another portion~~ of the surface side of chip 1, a semiconductor integrated circuit for computing acceleration, and thin film resistor 4 for adjusting performance of the semiconductor integrated circuit are disposed. Protection 20 film 5 is formed on the surface side covering at least thin film resistor 4 but not covering distortion sensing resistors 3. On the rear side of chip 1, glass weight 6 is attached.

When acceleration is applied to ~~thus constituted this~~ conventional acceleration sensor, a stress is applied to weight 6, ~~then the~~. ~~The sensor then~~ 25 detects the acceleration with a deformation of distortion sensing resistor 3. When two axes detection is required, two identical sensors are disposed crossing with each other at right angles. An example of this type of conventional acceleration sensor is disclosed in Japanese Patent Unexamined

Publication No. H5-288771 (~~document 1~~JP '771).

- Another example of this type of conventional sensor is disclosed in Japanese Patent Unexamined Publication No. H5-80075 (~~document 2~~JP '075). Fig. 8 is a block diagram showing ~~a—constitutional~~ example of the acceleration sensor.
- 5 As shown in Fig. 8, the sensor is composed of piezoelectric element 11 outputting a signal corresponding to acceleration G, impedance converter 12 converting the signal output from piezoelectric element 11, filter 13 filtering an unneeded signal from the signal output from impedance converter 12, amplifier 14 amplifying a needed signal output from filter 13, alternating signal output 10 device 16 outputting an alternating signal synchronized with a synchronism of a timing signal input from an outside, and capacitor 17 connected in series between alternating signal output device 16 and piezoelectric element 11.

- A voltage signal output from ~~thus constituted~~this conventional acceleration sensor is input to measuring/operating unit 18 and controller 15.
- 15 When two axes detection is required, two identical sensors are disposed crossing with each other at right angles for detection.

In the acceleration sensor in ~~document 1~~JP '771, a several percent of change in resistance value can be identified with a semiconductor resistor distortion formula. However, ~~a problem exists that in this device,~~ accurate 20 acceleration detection is difficult because ~~the~~ variance in the change of the resistance value is wide and ~~a signal~~s signals ~~is~~are affected by a change in ~~the~~ temperature of ~~the~~ processing circuits.

With ~~a constitution in document 2~~the device in JP '075, where the piezoelectric element is used for detecting displacement speed of the element, 25 detecting of such as a component of static gravitational acceleration is difficult because of its detecting mechanism. Two sensors are required for two axes detection. Thus, ~~problems of~~ cost increase and possible variation in performance exist.

SUMMARY OF THE INVENTION

This invention includes an element comprising a frame, a pair of diaphragmsbeam shaped members linearly and oppositely disposed on the frame, an under part electrode which is successively stacked on the diaphragmbeam shaped member, a piezoelectric thin film, an upper part electrode, a support body supporting the diaphragmsbeam shaped members at an adjacent one end of each diaphragmbeam shaped member, and a holding part holding the support body slidably in a linear direction, in which the diaphragmsbeam shaped members are extended and retracted by an acceleration transmitted to the support body through the holding part of the element, and in which the acceleration is detected through a change in a natural oscillation frequency of the diaphragmbeam shaped member. A pair of diaphragmsbeam shaped members are linearly and oppositely disposed crossing the pair of diaphragmsbeam shaped members that is linearly and oppositely disposed on the frame, detecting the acceleration in two axes directions. With this arrangement, both static and dynamic acceleration can be detected along two axes directions without being affected by noise or other environmental change. Thus, a highly reliable vibration piezoelectric acceleration sensor which operates under severe temperature changing environment is provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing a structure of an element of a vibration piezoelectric acceleration sensor (VAS) in accordance with a first embodiment of the present invention.

Fig. 2 is a perspective view showing a structure of a diaphragmbeam shaped member of the VAS in accordance with the first embodiment of the

present invention.

Fig. 3A is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

5 Fig. 3B is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 3C is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

Fig. 3D is a drawing showing a constitution of a VAS in accordance with the first embodiment of the present invention.

10 Fig. 4 is a circuit diagram showing a constitution of 2 axes detection of the VAS in accordance with the first embodiment of the present invention.

~~Fig. 5A is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.~~

15 Fig. 5A is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5B is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5C is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

20 Fig. 5D is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

Fig. 5E is a production process drawing showing a production method of the VAS in accordance with the first embodiment of the present invention.

25 Fig. 5F shows a production process of the VAS illustrating its production process in accordance with the first embodiment of the present invention.

Fig. 6 is a drawing showing a constitution of a control system of an airbag using a VAS in accordance with a second embodiment of the present invention.

Fig. 7 is a sectional view showing a constitution of a conventional acceleration sensor.

Fig. 8 is a block diagram showing a constitution of another conventional acceleration sensor.

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REFERENCE MARKS IN THE DRAWINGS

- 20 Si layer
- 21 substrate
- 22 SiO₂ layer (etching stopper)
- 10 23 diaphragmbeam shaped member
 - 23a, 23b, 23c, 23d diaphragmbeam shaped member
 - 23e, 23f, 23g, 23h, 23i arm
 - 24 under part electrode
 - 25 piezoelectric thin film
- 15 26 upper part electrode
 - 26a detecting electrode
 - 26b driving electrode
 - 27 resist
 - 28 side ditch
- 20 29 hole
- 30 side hole
- 31 frame
- 32, 32a, 32b, 32c, 32d holding part
- 33 support body
- 25 34 basal part
- 35 element of VAS
- 36a signal detecting line
- 36b signal driving line

- 38 amplifying circuit
- 39 F/V converter
- 40 AGC circuit
- 41 VAS device
- 5 41a, 41b, 41c, 41d VAS
- 42,43 differential circuit
- 44 vehicle body
- 45, 46 airbag
- 47 airbag ~~meuth~~-opening device
- 10 48 driver
- 49 moving direction

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS THE INVENTION

15 Following, ~~preferred~~-embodiments are explained in detail with reference to the drawings. The drawings are schematic diagrams and they do not necessarily show correct dimensional relationships between the ~~constituentelements~~.

20 FIRST EXEMPLARY EMBODIMENT

As shown in Fig. 1 and 2, ~~diaphragmsbeam shaped members~~ 23a to 23d having a natural oscillation frequency are disposed in frame 31. Support body 33 changes the natural oscillation frequency of ~~diaphragmsbeam shaped members~~ 23a to 23d. Holding parts 32a to 32d are formed in a meandering manner for holding the support body in a ~~slideablemoveable~~ manner and in a linear direction. In this ~~constitutionembodiment~~, ~~diaphragmsbeam shaped members~~ 23a to 23d extend and retract freely, therewith acceleration can be detected in a highly responsive and a highly accurate manner without being

affected by a change in temperature.

Diaphragmbeam shaped member 23a is formed in a ~~wedge~~ generally rectangular shape and has basal part 34 at each end of the diaphragmbeam shaped member, one basal part 34 being held by frame 31 and an other basal part 34 being held by support body 33. Support body 33 is held by frame 31 via holding part 32a formed in the meandering manner, thus moving back-and-forth in a linear direction. Here, only diaphragmbeam shaped member 23a disposed on frame 31 is explained, but ~~at the same principle is applied to other diaphragmsbeam shaped members~~ 23b to 23d, so further detailed explanation ~~on them are~~s omitted.

Arm 23i ~~is can be~~ formed ~~like being extended as extending~~ from basal part 34. By forming arm 23i, sharpness of resonance frequency is increased by at least 2 to 3 times, and the increased resonance sharpness enhancing an accuracy of detection. Because a higher change ratio of resonance frequency can be obtained with acceleration, the acceleration can be detected highly accurately without being affected by a change in temperature.

Following, configuration of the diaphragmbeam shaped member is explained in detail taking diaphragmbeam shaped member 23a as an example in Fig. 2.

Diaphragmbeam shaped member 23a as illustrated in Fig. 2 is composed of Si layer 20 formed on SiO₂ layer 22, under part electrode 24 formed on Si layer 20, piezoelectric thin film 25 formed on under part electrode 24, and an upper part electrode formed on piezoelectric thin film 25. The upper part electrode is composed of driving electrode 26b and detecting electrode 26a. Driving electrode 26b and detecting electrode 26a are formed along a center part of the wedge shape constituting diaphragmbeam shaped member 23a, and the electrodes are extendedly formed onto support body 33 and frame 31. WithIn this constitutionembodiment, a center portion of holding part 32a

vibrates least ~~not generating, thus the displacement does not generate significant electromotive force by displacement~~, so that ~~a~~ modulation signal is hardly scarcely interposed ~~on~~ ~~at~~ ~~the~~ resonance frequency of ~~diaphragmbeam shaped member~~ 23a, thereby only ~~the~~ resonance frequency of ~~diaphragmbeam shaped member~~ 23a can be detected.

Furthermore, driving electrode 26b and detecting electrode 26a has a tapping electrode (not illustrated) at a predetermined part of the electrode extended to frame 31, and the tapping electrode is drawn to a control circuit (not illustrated). Since the tapping electrode is disposed on non-vibrating frame 31 without influencing vibration of ~~diaphragmbeam shaped member~~ 23a, acceleration can be detected highly accurately without being affected by a change in temperature.

Still furthermore, driving electrode 26b and detecting electrode 26a are disposed symmetrically with respect to a central axis that crosses a longitudinal direction of ~~diaphragmbeam shaped member~~ 23a and equally divides ~~diaphragmbeam shaped member~~ 23a. By dividing an effective area of ~~diaphragmbeam shaped member~~ 23a equally, detecting sensitivity through driving of ~~diaphragmbeam shaped member~~ 23a and detecting from ~~diaphragmbeam shaped member~~ 23a is maximized.

Next, ~~the working principle of thus constituted this~~ vibration piezoelectric acceleration sensor (VAS) in accordance with the exemplary embodiment is explained. Drawings 3A to 3D show constitution of the VAS in accordance with the exemplary embodiment, and each drawing having corresponding ~~diaphragmbeam shaped member~~ 23a to 23d. Element having ~~diaphragmbeam shaped member~~ 23a as illustrated by Fig. 2 is shown by an equivalent circuit 35.

The VAS includes signal detecting line 36a, signal driving line 36b, amplifying circuit 38 for amplifying a weak signal and driving ~~diaphragmbeam shaped member~~ 23a of element 35, F/V converter 39 for converting a frequency

of input signal into a voltage, and AGC circuit 40 for controlling a voltage level of output signal from amplifying circuit 38. Element 35 is attached to a main body (not illustrated) likewisesimilarly to the main body holding element 35 with frame 31.

5 First, when anelectricpower is input to VAS 41a, a signal including a
noiseforamplification is input to amplifying circuit 38forbeingamplified.
The amplified signal is input through signal driving line 36b to driving
electrode 26b of element 35, vibrating diaphragmbeamshapedmember 23a.
ElectricalAnelectrical charge is excited at piezoelectric thin film 25 in
10 diaphragmbeamshapedmember 23a to detecting electrode 26a, which is input
from detecting electrode 26a through signal detecting line 36a to amplifying
circuit 38. This process in the closed loop is repeated until the signal is
stabilized into a stationary state of resonance frequency of natural vibration.
Then, the resonance frequency signal of natural vibration is input to F/V
15 converter 39 and is converted to a predetermined voltage. AGC circuit 40
worksisoperable when a voltage level that is output from amplifier 38 becomes
too large to cause a distortion of the signal, namely theAGC circuit acts
achieving an accurate F/V conversion without an error.

When acceleration is applied from an external source, an inertia force is
20 applied from frame 31 to support body 33 held by holding part 32a, moving the
support body in back and foreforth directions along a linear line. With this
back and forth movement, diaphragmbeamshapedmember 23a vibrating in a
stationary state contracts and retracts changing the resonance frequency of
natural vibration of diaphragmbeamshapedmember 23a. Thus, the change in
25 the resonance frequency of the natural vibration is detected, corresponding to
the acceleration applied. WithIn this constitutionembodiment, a higher
change ratio of the resonance frequency can be obtained, namely acceleration
can be detected highly accurately without being affected by a change in

temperature.

In the above explanation example, only diaphragmbeam shaped member 23a is explained. Since other diaphragmsbeam shaped members 23b to 23d are corresponded to Fig. 3B to 3D and their working mechanism is similar to 5 23a, explanation of them is omitted.

Fig. 4 shows a constitutionan embodiment of a main body of VAS 41. It is a two axes detection system in which differential circuit 42 and 43 each obtaining a differential voltage as an output signal from VAS 41a to 41d, making them an acceleration detection signal of X-axis and Y-axis. Because 10 differential circuits 42 and 43 differentially cancel out changes in performance of each element and circuit, further stabilization can be expected.

Following, the production method of the VAS in accordance with the exemplary embodiment is explained. Figs. 5A to 5F are production process drawings showing a production method of the VAS in accordance with the 15 exemplary embodiment, each illustrating cross sectional viewviews of a center part of diaphragmbeam shaped member 23a.

First, as illustrated in Fig. 5A, forming-etching stopper 22 made of SiO₂-is formed on substrate 21, which is made of Si for stopping etching, then forming Si layer 20 is formed on etching stopper 22. ThicknessThe thickness of substrate 21 is 500μm, etching stopper 22 is 2μm, and Si layer 20 is 10μm.

Following, forming-Ti is formed in a thickness of 50Å on Si layer 20 by high frequency sputtering, and then forming-platinum in a thickness of 2000Å, constitutingis formed under part electrode 24, as illustrated in Fig. 5B. Next, forming-piezoelectric film 25 made of PZT (Lead Zirconate Titanate) is formed 25 in a thickness of 25μm on the platinum, then forming-Ti layer is formed in a thickness of 100Å on piezoelectric film 25 by vapor deposition, using a metal mask for obtaining a desired pattern, and then similarly forming-gold is formed in a thickness of 3000Å on the Ti layer by vapor deposition, thus constituting

upper part electrode 26 having a prescribed pattern. Next, forming resist 27 is formed on the gold, a-resist 27 for serving as an etching mask. AThe reason for using PZT material is for obtaining to obtain a higher conversion of resonance frequency changed by acceleration.

5 Next, forming-side ditch 28 is formed shown in Fig. 5C. In addition to the above explained diaphragmbeam shaped member, support body 33 and holding part 32 can be made of Si, therewith the resonance frequency correspondingly changing with the stress of diaphragmbeam shaped member 23 caused by acceleration can be stably improved.

10 Next, as shown in Fig. 5D, forming-resist 27 is formed in a predetermined pattern at a rear side of substrate 21, and then etching the rear side of substrate 21 is etched, forming hole 29.

Next, as shown in Fig. 5E, etching the side of resist 27 is etched again, forming side hole 30. Then, removing-resist 27 is removed at the rear side. 15 Thus, diaphragmbeam shaped member 23 in a thin size and in a wedge shape is manufactured, as shown in Fig. 5F.

Detection sensitivity can be further improved by adding mass to an upper or a lower surface of support body 33. Increased mass of support body 33 strengthens the stress applied to diaphragmbeam shaped member 23a, 20 increasing a degree of change in the resonance frequency caused by acceleration, thus raising the detecting sensitivity.

SECOND EXEMPLARY EMBODIMENT

Fig. 6 shows an airbag control system, an application example of VAS 41 25 of the invention. VAS 41 is installed in the X-axis and the Y-axis direction directions. The control system is explained with reference to vehicle body 44, front airbag 45, side airbag 46, mouth-opening device 47 and driver 48. Arrow mark 49 indicates a moving direction of the vehicle.

Thus installed, VAS 41 of the present invention controls workswork in vehicle 44 by controlling acceleration. When an acceleration value exceeds a certain level, the sensor sends out an acceleration output signal to airbag ~~meouth~~-opening device 47 for opening the airbag. The ~~meouth~~-opening signal is
5 then transmitted to airbags 45 and 46 opening the airbag, thus realizing a-safe driving with the sensor.

If acceleration is generated by a collision in ~~at~~the moving direction (X-axis direction), front airbag 45 is opened, and if acceleration is generated in a side direction (Y-axis direction), the acceleration signal in right and left directions
10 opens side airbags 46, thus a fatal human accident is prevented. Since 2 axes acceleration detection is ~~made~~done for both the front airbag and the side airbag, a high level of safety control is ensured.

In VAS 41, in accordance with the exemplary embodiment, vibration piezoelectric sensor 41 senses acceleration applied to vehicle 44 somewhat
15 differently depending on a position where the sensor is placed, therefore vibration piezoelectric acceleration sensor 41 is preferably disposed in a central part of the vehicle 44 for detecting an average acceleration. Accordingly, in this exemplary embodiment, VAS_41 is placed in a central part of the vehicle. Positional relationship between a driver and an airbag in a vehicle is not
20 limited to one arranged in this exemplary embodiment. Even if the driver is sitting ~~at~~in the left side of the vehicle with regard to the moving direction, an identical effect is provided.

25 INDUSTRIAL APPLICABILITY

The VAS according to the present invention detects a high change ratio of resonance frequency caused by acceleration, and the acceleration can be detected highly accurately with two detections without being affected by a

change in temperature. Accordingly, the sensor can be used for an airbag control system, as well as for a sensor detecting gravity ~~on the earth~~ as a static acceleration. The static acceleration detecting capability can be utilized for a sensor detecting an angle of inclination, and the angle of inclination detection capability can be utilized for a navigator navigating a three dimensional position including an altitude.

ABSTRACT

A vibration piezoelectric acceleration sensor including a pair of diaphragmsbeam shaped members linearly and oppositely disposed on a frame, a support body supporting the beam shaped memberdiaphragm, and a holding part holding the support body slidablymoveably in a linear direction, and another pair of beam shaped membersdiaphragms disposed linearly and oppositely crossing the pair of beam shaped membersdiaphragms detecting acceleration in two axes, i.e. X and Y directions. The beam shaped membersdiaphragms are extended and retracted by the acceleration transmitted to the support body through the holding part, changing a natural oscillation frequency. Accordingly, a high change ratio of resonance frequency can be provided with the detection of the acceleration, and the acceleration in the direction of two axes-directions can be detected without being affected by a change in temperature.

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